E/CONF.39/A/321
2 Nov.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.5.2.2

United Kingdom

SOME RECENT DEVELOPMENTS IN THE MECHANISATION OF SMALL UNDERGROUND MINES

By D. SUTTON,
A.R.S.M., B.Sc., A.M.I.M.M.

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Some Recent Developments in the Mechanisation of Small Underground Mines.

by D. SUTTON A.R.S.M., B.Sc., A.M.I.M.M.

1. By force of economic necessity, few small metalliferous mines in the world today, however remotely situated or richly endowed with ore, can afford to ignore mechanisation in some degree for selected operations. This is especially true, perhaps, where the mineral products have to win acceptance in world markets rather than serve indigenous requirements for industry or stockpiling; but in all cases, considerations concerning expediency, an overall lowering of the average grade of ore available and the general price and scarcity of suitable labour indicate mechanisation as ultimately inevitable and have led to accelerating adoption of mining machinery on a world-wide basis in recent years.

2. The degree of mechanisation to be attempted in any particular case, however, together with optimum selection of equipment and working method, depend largely upon a unique assemblage of local conditions which themselves defy rigorous analysis. The problems involved are therefore far from straightforward and if the best results are to be obtained with a minimum of delay it is often wise to call on the experience of others.

3. But whose advice is to be sought? Every potential supplier of equipment will naturally have an interest in magnifying the suitability and importance of his own particular experience and equipment to the detriment of his competitors, thereby adding to the general uncertainty as to what is to be done. Experience can be, of course, acquired locally by trial and error procedures, but the expense in time and money will be unnecessarily large. Similar problems will usually have been encountered elsewhere but there again satisfactory solutions seldom become widely known. For these and similar reasons the best course to adopt probably lies in the use of professional consultants of high repute and even higher integrity noted for competent and impartial assessment, together with the engagement of skilled and experienced engineers who will be aware not only of the true potential of a mechanised operation but also of what is required in the way of additional workshop facilties, storekeeping and personnel.

4. However, even if full advangage is taken of the advice from all sources backed by the skill of experienced engineers it is natural that

the customer should wish to understand the basic reasoning behind the selection of a particular type of equipment or adoption of a particular working method, and it is for this reason that the more recent significant advances in equipment and technique are now summarised.

Shaft Sinking

5. When considering mechanisation of the initial shaft sinking stage of a mining operation it is necessary to offset expenditure on specialised sinking equipment against the saving in capital charges which result from an increase in the tempo of the work made possible by its use. On a cost per foot basis, especially in cheap labour areas, fully mechanised sinking may well prove more expensive than partial hand working, though a considerable overall saving may arise through achievement of an earlier return on invested capital.

6. Broadly speaking, mechanisation of the clearing of broken rock from the shaft bottom will only be considered where the total depth of sinking exceeds 1,000 ft. or so. Simultaneous sinking and lining, where applicable, will require greater depth still in order to effect overall economies. At the same time the small mine in shallow depth will be well advised to adopt other recent though less expensive time and labour saving techniques and to plan all operations in meticulous detail. For example, a suspended stage of simple design will be used for the installation of lining and shaft furniture, concrete for continuous or strip lining will be piped to the bottom directly from a surface batching plant, electric blasting from ring mains will be adopted, walls will be rock bolted where required as a temporary or perhaps permanent means of support and the work programme will be carefully tailored to suit cyclic operation on a 6 or 8-hour basis.

7. Drill jumbos mounting heavy machines remotely-controlled have found some application in small shafts in recent years but are an expensive luxury, even in most high wage-rate areas. Furthermore progress may be actually retarded due to their use since jumbos are unable to compete in overall drilling speed with hand-operated machines saturating the shaft bottom.

8. Outside the large mining groups more and more shaft sinking is being undertaken by specialist contractors who supply the necessary supervision and the more specialised items of equipment. Good results may also be obtained, however, using personnel recruited locally provided that suitable equipment is available and the entire project is placed in the hands of a thoroughly competent Master Sinker.

Lateral Development

9. The small mine will not usually wish to drive roadways exceeding 75 sq.ft. in cross-sectional area. Nor will it require ore and fill passes exceeding 50 sq. ft.

10. Drifting operations will be effected with greatest speed and economy by recourse to a modest expenditure in mechanisation. The drilling phase will be performed by percussive air-leg mounted machines preferably of 3 ins. bore. Unless the ground is exceptionally hard, taper-attached, detachable, tungsten carbide tipped chisel bits will be used in conjunction with 1 in. alloy steel rods. In very hard ground, integral steel will probably show an overall economy; in the hardest it will be essential.

11. Blasting will normally be undertaken by means of nitroglycerin-based explosives, safety fuse and igniter cord.

12. Broken rock will be loaded at the face by rail-mounted over-shot loader and suitable arrangements will be made for keeping the loader supplied with empty mine cars.

13. It is highly desirable to man a development end with versatile labour, so that one crew is capable of performing all operations at the face. The work may then be so planned that a full cycle of operations is completed within the span of a single shift: each crew enjoys a sense of accomplishment and in this way a high standard of overall performance is encouraged.

14. If the length of round and/or choice of equipment are such that either more or less than a full cycle of operations should be normally possible within a shift the speed of advance of the development end will be invariably affected adversely. Completion of one or two phases of the cycle within a shift is the next best objective for which to plan: although with such a system some sense of achievement is retained, apportionment of responsibility for sub-standard performance is rendered more difficult and the work programme becomes psychologically less conducive to sustained effort.

15. Raising is recognised as one of the more arduous and hazardous of underground mining operations, requiring above average skill and physical fitness from those assigned to it. Nevertheless it is doubtful whether the small mine would benefit appreciably from adoption of mechanised techniques unless elements such as speed or excessive length were a major consideration.

16. Where average raise length is of the order of 100 ft. or less it would be wise to investigate pre-drilling by long blast holes as a safe, low cost alternative to conventional raising methods, although a high degree of skill is required in obtaining and maintaining correct hole alignment for the method to be a success. At the same time the equipment required is standard and relatively inexpensive.

Ore Extraction

17. In the ultimate analysis, production from a mine depends upon the total length of working face available for mining attack and the mean intensity of its exploitation. The trend has been in recent years

towards a concentration of working places and a marked improvement in the tempo of extraction in each of them.

18. A factor of major importance in this connection has been the development of long hole drilling equipment which has been adopted on a very large scale and in a variety of applications, particularly for so-called "blast hole" stoping.

19. Hand in hand with improvements in drilling bits tipped with tungsten carbide have gone the development of specially treated fatigue-resistant extension steel rods and powerful percussive machines capable of operation in confined sub-levels. Using such equipment, holes may be drilled at any angle to depths of 100 ft. or so with ease, speed and acceptable cost.

20. Diamond drilling equipment has seen extensive use also in blast hole mining and renders comparatively trouble-free service. It tends, however, to be rather more expensive in overall cost per ton broken and for this reason its use is declining in favour of its percussive counterpart.

21. In most stoping operations at some stage the amount of expensive development footage required for access openings is related to the length of blast hole used in the extraction phase. It follows that, other things being equal, the longer the blast hole which it is practical to drill the lower will be the cost of access development, and it is precisely for this reason that the present tendency is to design working layouts with reference to a blast hole length of about 100 ft. This leads not only to important savings in access footage but to a less discontinuous cycle of operations and to a higher standard of safety within the stopes.

22. Aside from sub-level stoping, blast hole mining has been widely applied to the extraction of pillars and remnants, also to the isolation and undercutting of blocks of ground prior to caving.

23. Some shrinkage stoping has been successfully undertaken by means of horizontal fans of holes drilled from peripheral raises, also some sub level caving using vertical fans from more widely spaced access development.

24. Other significant though less important recent applications of long hole drilling equipment include the pre drilling of shallow shafts and raises and provision of conveyance holes for hydraulic fill, hoisting rope, electrical cables and drainage water.

25. "Satellite" mining opens up interesting possibilities. This new method involves the initial excavation of a parent opening from which, by means of partially charged long holes, parallel excavations radially disposed may be formed. Suitable layouts are used typically in stoping by room-and-pillar or by sublevel caving methods and savings in cost of up to 20 per cent. arise chiefly from the more efficient use of explosives.

Blasting with AN/FO Explosives

26. Close on the heels of the almost universal adoption of ammonium nitrate/fuel oil explosives for opencast mining purposes has come increasing recognition of the advantages in safety and cost to be gained through their use in small diameter boreholes underground.

27. Much research has been directed recently towards a better understanding of the properties of AN/FO mixtures in small borehole applications with particular reference both to safety and to their efficiency as blasting agents. From the results of all such research work published to date it is concluded that although AN/FO mixtures are sensitive to variations in composition, moisture content and strength of initiation, nevertheless dry, well-mixed, oxygen-balanced mixtures initiated by strong primers in well ventilated surroundings are very reliable and safe for use in small boreholes underground.

28. Both the mixing and the loading of AN/FO blasting agents have been effectively mechanised, adding further advantages in speed and cost to the very considerable saving in cost of materials as compared with nitroglycerine-based explosives.

29. AN/FO explosives are used to best advantage in dry ground where best results are obtained with a 60% NG explosive. Such explosives are unsuited, however, to tough ground normally requiring a high grade NG explosive, nor do they find satisfactory application in wet conditions such as exist for example, in shaft sinking and the bottom holes of development rounds. Their efficiency in shattered ground is also doubtful.

Ore Handling

30. Recent advances in the handling of broken ore and dry fill in the vicinity of the stope face, and from the face to the haulage drive have been less marked than elsewhere, but there has been a noticeable increase in the application of scrapers. The scraper, of course, is far from being a new device, but its modest cost, flexibility and useful capacity are being exploited on a larger scale than formerly.

31. In steeply inclined deposits, handling by gravity is naturally employed whenever possible consistent with the development footage involved and the cost of installing and maintaining numerous loading chutes, but in flat deposits scrapers are indispensable.

32. Loading machine draw points are losing ground in favour of scraper drifts. Drawpoints equipped with overshot loaders or scraper slides are capable of high outputs with well fragmented ore but lose this advantage when frequent stoppages are occasioned by secondary blasting. Since there is no storage between drawpoint and mine car with this system, any blockage due to large ore necessarily results in lost production and poor utilisation of an expensive machine.

33. In all stoping areas any apparent economy of small, hand-operated

loading boxes should be initially regarded as fallacious. Such devices are invariably an insufferable bottle neck expensive in labour, dynamite, maintenance charges and - above all - lost production. Loading boxes reward good design, generous dimensions and the modest expense of an air-operated chute door.

34. Steel loading boxes rock bolted in place have given good results for loading from shrinkage stopes. Installation and maintenance charges were both low and several re-uses were possible for the same box.

Ground Support

35. For undisturbed production, avoidance of dilution, high percentage extraction and good safety, close control of rock pressure and development of loose throughout the workings of the mine are obvious essentials.

36. In the general field of ground support over the past decade two developments have been outstanding, viz. rock bolting and hydraulic back filling.

Rock Bolting.

37. As a means of supporting the walls of shafts and the walls and backs of stopes and roadways, rock bolting has won universal acclaim. Bolting techniques are used to an increasing extent to compact the peripheries of tunnels through competent rock and also find application in rock which is inherently self-supporting to reinforce against pressure bursts.

38. In tunnelling operations through unstable ground, rock bolting has replaced both steel arch and timber support to some extent. In such applications the length of bolt used should be at least equal to the depth of round. Bolt Spacing is calculated from the load which can be safely placed upon each bolt together with the "dead weight" of the assumed rock volume to be supported. The safe working load is taken as 50 per cent. of the load at which the anchor yields or the bolt begins to deform plastically. For best results, bolts should be placed as soon after blasting as possible.

39. Effective anchorage is a function of the type of rock. In a sound, medium-hard rock the anchor will normally withstand a greater load than the bolt and the bolts may be stressed initially to 50 per cent. of their maximum permissible load. Where the rock is either soft, or very hard, however, effective anchoring may be difficult, rendering it impracticable to impart the desired working load to the bolt. In such cases either more closely spaced smaller diameter bolts with increased anchoring surfaces may be employed or the bolts grouted into place.

40. The simplest effective method of introducing grout into a bolt hole consists in merely ejecting the grout from a plastic "gun" under the action of a hand-operated plunger. The gun is inserted to the bottom of the hole, having been previously charged with grout of a suitable consistency by reverse action of the plunger. By judicious

selection of the size of the gun barrel the length of the ejection stroke may be made equal to the length of the grout anchor after insertion of the bolt, the requisite length having been previously determined from field trials.

Hydraulic Back Filling

41. As extraction proceeds in depth, it eventually becomes necessary to fill with waste material the voids created by removal of ore. This is done in order to stabilize the walls of the excavation, thereby facilitating the removal of pillars and the continuance of extraction in still greater depth.

42. Until comparatively recent times the fill material largely comprised sand, gravel, or broken rock imported into the mine from surface. These materials required surface excavation and transport, provision of fill passes into and within the mine, underground tramming to individual stopes and equipment for handling the fill in the stopes. Since the tonnage of fill required is about 60% of the tonnage of ore extracted it is obvious that stope filling operations add very appreciably to the working costs of the mine.

43. Great advantages in speed, cost and general expediency have been realised in recent years through the transport and placing of suitable fill material by hydraulic means. The fill material, usually mill tailing, after treatment in hydrocyclones to reduce the slime content is mixed on surface to a dense pulp averaging some 65% solids in water and as such it is supplied via boreholes and pipes direct to the stopes.

44. In cut-and-fill mining, the most important advantage of hydraulic fill is the saving in time required to fill a working floor thus shortening the non-productive part of the extraction cycle and increasing ore production in some instances by as much as 50%.
Other advantages include:-

(a) Elimination of expensive fill passes.
(b) Reduction of non-productive load on surface and underground transport facilities.
(c) Provision of a hard, level working floor in the stope.
(d) Extremely effective support of stope walls and stabilization of timber packs or square sets.

45. Provided a free-draining fill is used and that suitable precautions are taken to minimise delays due to blocked pipes, the method has no serious disadvantages.

46. It is obviously necessary when considering an application of hydraulic filling to ensure the availability of sufficient quantities of suitable fill material. By "suitable" is meant a sand having the following properties:-

(a) An initial percolation rate exceeding 2 inches per hour. Since some segregation during placement is inevitable it may by advisable to keep the percolation rate of the feed material above 4 inches per hour.

(b) Continued ability to drain in the presence of ground water. Due to re-orientation of the sand particles and to some migration of "fines" the percolation rate falls to a low value with time. Test should establish that the final percolation rate is acceptable.

(c) Sufficient strength after draining in cases where there is a requirement for pillar removal against sand-filled areas.
Sands consisting of angular particles of well-mixed sizes are best in this respect.

47. Hydraulic sand fill is usually obtained from mill tailing by removal of all but a few per cent. of -325 mesh material in hydrocyclones. Noxious or toxic substances must also be removed. With some treatment processes however, the tailings are so finely ground that the volume of contained +325 mesh material is inadequate, in which case the supply will have to be augmented with other suitable material, e.g. river sand, granulated slag.

48. Using 3 in. diameter pipes and boreholes, placing will be at rates approaching 1 ton of solids per minute, and it is normally possible to work on the surface of hydraulically placed fill ore hour after placing.

49. Continuous pipe runs of up to 13,000 ft. have been used for hydraulic fill in one instance with negligible pipe wear. Remote control of an entire delivery network by one man stationed in the stope has also proved successful.

Haulage and Hoisting

Diesel Haulage

50. Although electric battery and trolley locomotives are still widely used in the worlds underground metal mines, the adoption of diesel haulage is growing slowly.

51. Diesel-engined locomotives are self-contained and service is simple: operating and first costs are usually lower than with electric haulage and they are free of the limitations imposed by battery capacity or trolley wire installation.

Belt Conveying

52. Many more conveyor belt installations are to be foound in metal mines now than formerly, although transport by conveyor belt is best suited to flat orebodies and large outputs. Where a high load factor can be maintained, the conveyor belt offers the lowest cost per ton mile of horizontal haulage obtainable underground.

53. The practice of hoisting by conveyor incline has seen some application in metal mining in recent years. However, recent developments in high tension belts, and more particularly in the application of cable

belts, have reduced installation and operating costs still farther and make conveyor belt hoisting in moderate-depth more attractive.

Friction Drive Hoisting

54. Friction drive hoists have been adopted in metal mining increasingly over the past few years. As compared with drum-type hoists they possess several important advantages arising chiefly from the comparitively small size of the hoisting units and the simple incorporation of multiple ropes. Less rope wear results from elimination of multi-layer storage under high tensile loads and power requirements are often lower. Rope changes, however, are more difficult, rope lubrication must not be carried out and re-capping is impracticable. In the event of the shaft being deepened a new set of ropes would automatically become necessary.

Skip and Cage Hoisting

55. Ore removal from mines served by shafts is today invariably effected by skip hoisting. Compared to hoisting in mine cars, a large increase in shaft capacity is achieved at modest, if any, additional expense.

56. At the small mine, primary crushing is usually done on surface, in which case especially with ores which tend to break big, close attention must be paid to the provision and correct use of stope and ore-pass grizzleys. Underground crushing is usually only justified where the shafts are deep and the hoisting system highly automated.

57. In new skip hoisting installations the trend in recent years has been towards bottom and side - dump skips in preference to the overturning type. The former require less height in the headframe and tip more cleanly and evenly in a shorter time than the latter.

58. When initially planning the size of the main access shafts to a mine it is always good policy to provide for service cages of generous dimensions, so that the largest pieces of equipment likely to be required underground may be handled with ease and safety.

59. Aluminium alloys have been used to good advantage in cage and skip construction in recent years, reduction of the weight of the conveyance making for increased payload capacity and a useful saving in power cost per ton of ore hoisted.

60. Hoisting in general has become more fully automated in recent years, with improved electrical circuits replacing manual controls. Installation of remotely-controlled ore hoisting is one positive way of increasing shaft capacity at moderate cost.

Compressed Air Supply

61. For every ton of ore mined and concentrated in the modern metal mine something of the order of 3,000 cu.ft. of free air compressed initially

to 105 -110 p.s.i.g. is consumed. This forms an appreciable proportion of operating costs and it is therefore important that every economy in the use of this convenient though highly inefficient source of power should be observed.

Screw Compressors

62. Aside from the largest base load stations using turbo-compressors it now appears certain that the recently developed screw type of compressor will become standard equipment to the virtual exclusion of all others.

63. In comparison with a piston-type compressor, the screw machine requires considerably less floor space and absence of unbalanced forces reduces foundation requirements. Owing to the high speeds at which screw compressors operate they may be driven by comparatively inexpensive squirrel cage induction motors of high efficiency and good power factor. Furthermore, since bearings and timing gears are the only parts subject to wear, overhauls are infrequent and maintenance charges low.

Lighweight Piping

64. The use of aluminium or lightweight steel alloy pipes for both compressed air and water service mains underground has found favour in recent years. Compared to standard piping, the principal advantage of the new materials lies in a weight reduction of about 60 per cent which greatly facilitates handling and reduces the number and size of hangers required. Both types of piping are, however, prone to physical damage and corrosive attack for which there is no satisfactory remedy.

65. A reduction in price of polythene piping would make this material immediately attractive for use underground. Some is already in use in operations such as raising and hydraulic filling where requirements both as regards flexibility and extensibility are all-important.

Concentration of Output

66. Partly as a result of mechanised working, partly in order to take full advantage of the production potential which it affords, a marked concentration of higher intensity production from a smaller number of working places has come about in recent years.

67. Concentration of output has the overall effect of reducing the level of unproductive effort, both physical and mechanical, involved in the running of a mine, thereby tending to the best possible load factor on men and machines. Ventilation requirements are reduced and simplified; transport systems become less tenuous; mine services are reduced in extent and in maintenance requirements, and supervision is less dilute.

68. In metal mines, however, concentration of output can lead to difficulties with grade control and here, as elsewhere, concentration magnifies the deleterious effects of unforseen contingencies.

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